Rockford, Illinois, Semi-continuous Ambient Lead Investigation

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February 5, 2015

Executive Summary

The main objective of this study was to determine whether lead (Pb) concentrations in ambient air near the Behr Iron & Metal facility in Rockford, Illinois, exceed or have the potential to exceed the Pb National Ambient Air Quality Standard (NAAQS). The Pb NAAQS is violated when any 3-month rolling average is higher than 150 nanograms per cubic meter (ng/m^3). The potential to exceed the NAAQS, which according to EPA guidance is the basis to require long-term air monitoring, is defined as short-term monitoring or modeling with results greater than 50% of the NAAQS (75 ng/m^3). The potential to violate is not a strict criterion –the ultimate decision is up to the discretion of the EPA Regional Office. A secondary objective of this monitoring project was to determine whether toxic metals are higher than EPA's short-term and long-term health screening values, as measured in total suspended particulates (TSP).

The EPA metals trailer was deployed at Nelson Park, directly north of Behr, from May 6 to November 14, 2014. Lead concentrations during the highest month averaged 80 ng/m^3 (53% of the NAAQS). The highest 3-month average was 67 ng/m^3 (44% of the NAAQS). Peak concentrations corresponded to periods when the monitor was downwind of Behr's lead recovery rotary furnace. This is adequate demonstration of the potential to violate the NAAQS. The monitor was sited in a location that was not necessarily the area of maximum impact. Ordinarily EPA requires dispersion modeling to pick the ideal monitor location; modeling results and on-site meteorology were not available to support this study. Also, EPA prefers to have three years of data to rule out the potential to violate the NAAQS. This short-term study shows the need for dispersion modeling and long-term lead monitoring in this community.

We also identified potential health risks from arsenic (As), which is a carcinogen and also has multiple noncancer effects. Arsenic was measured with a peak 1-hour concentration of 291 ng/m^3, which exceeds California EPA's Reference Exposure Level (REL) of 200 ng/m^3. The highest 8-hour average was 62 ng/m^3, which is more than four times the REL of 15 ng/m^3. The 8-hour REL was matched or exceeded on four additional dates, with peak 8-hour averages ranging from 15 to 19 ng/m^3. The short-term RELs for arsenic are based on developmental health effects, specifically decreased intellectual function in children, as well as impacts on the cardiovascular and nervous systems. Although As air reference values were exceeded relatively few times, it should be noted that this was a short-term study and other factors relevant to human health risk evaluation were not considered, including: cumulative inhalation risk for metals and other emissions from Behr; long-term facility operation with the potential air-to-soil deposition of metals; and combined risks from ingestion exposure to arsenic. This study supports the importance of emissions modeling and long-term ambient metals monitoring to better characterize potential health risks.

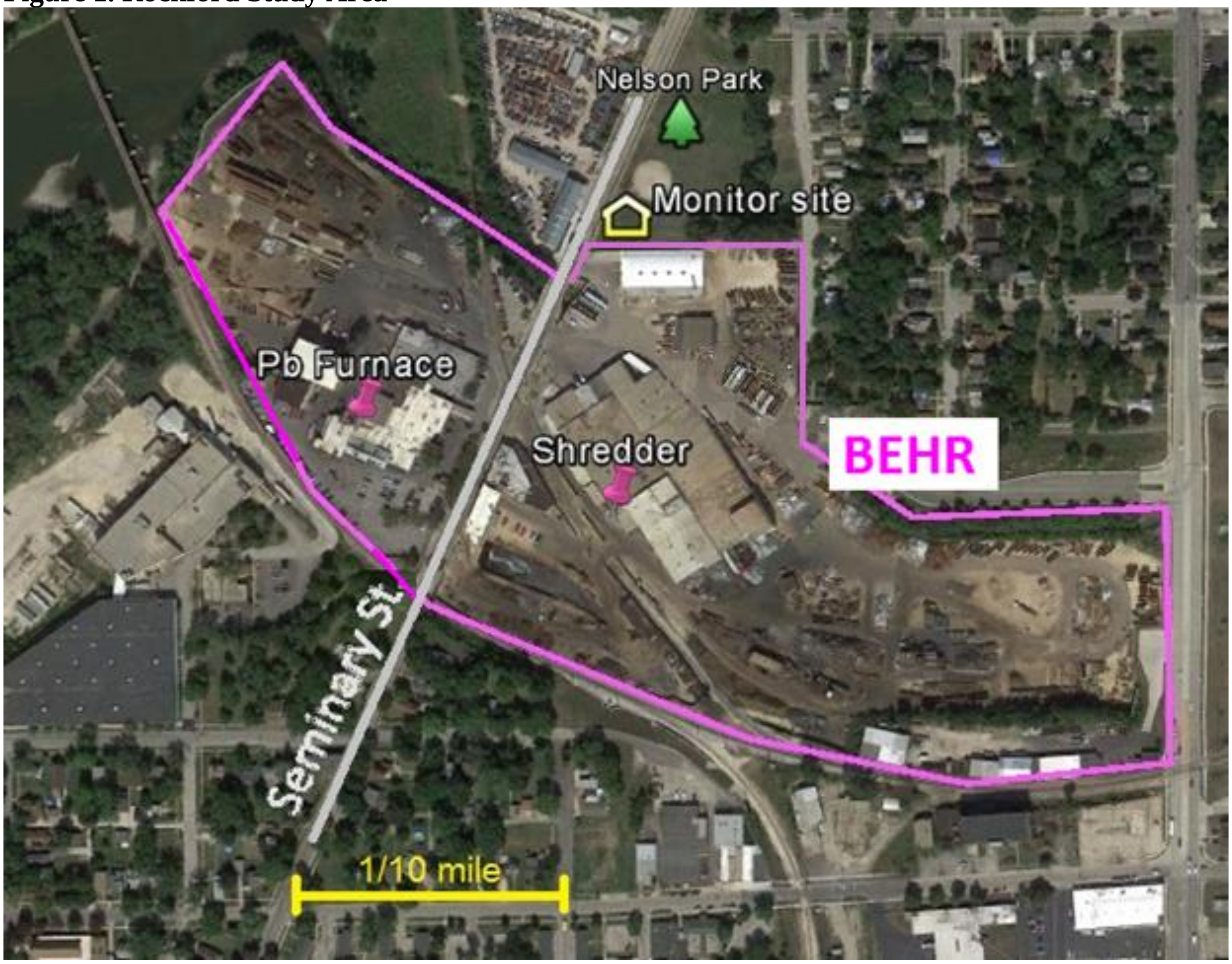
Background

Study background and methodology are documented in the Quality Assurance Project Plan "Rockford, Illinois, Semi-Continuous Ambient Lead Investigation" version 1.0 dated May 6, 2014. The EPA trailer was deployed on Rockford Park District property in Nelson Park. See map on Figure 1. The station was about 200 meters northeast of the lead recovery rotary furnace, which was suspected to be a source of lead emissions. The Behr complex is divided by Seminary Street into east and west sections. The lead furnace is the west side; there is a hammer mill shredder and various outdoor storage piles on the east side.

Quality Assurance Review

Metals measurements were of sufficient quantity and quality for project objectives. Results from each individual sample hour were quality-checked according to the EPA Xact Standard Operating Procedures and study QAPP. Specific quality assurance criteria and findings are described below.

Figure 1. Rockford Study Area



1) Data completeness should be ≥75%, or 1620-2160 samples, over a 90 day period;

- The EPA metals trailer operated from May 6 through November 14, 2014. There were 22 hours of data invalidated because the sample flow rate was below acceptable limits. The metals monitor was offline during brief routine field visits for equipment maintenance and additional hours were lost due to brief technical issues. A total of 4473 valid samples were collected over a period of 192 days or 4612 possible samples. Completeness was 4473/4612 * 100% = 97%.

2) The lowest non-zero values reported in this study should be equal to or lower than the detection limits (DLs) specified in the instrument manual. DLs and lowest reported values are shown below on Table 1.

- Lead and toxic metals were measured well below expected DLs during this study.

Table 1. Metals DLs and lowest reported concentration of toxic metals in Rockford study, ng/m^3

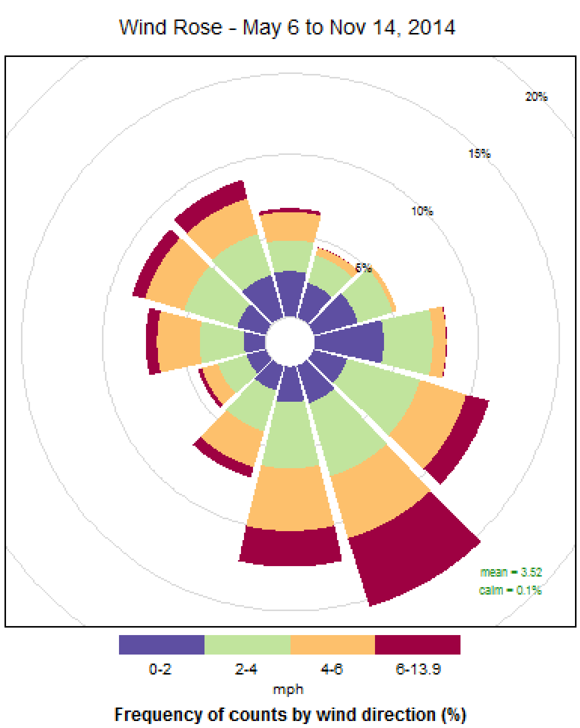
Metal	DL	Lowest Reported
Arsenic	0.051	0.010
Lead	0.099	0.465*
Manganese	0.077	0.231**
Nickel	0.083	0.001
Chromium	0.092	0.001
Cadmium	1.138	0.057*
Mercury	0.0912	0.001

* There were no nondetects for Pb and Cd in this study.
** There were ten hours of nondetects for Mn.

3) Sufficient samples should be collected when the predominant wind direction is from the target source(s).

- Southwest, south, and southeast winds were the most desirable for this study because they resulted in the metals trailer being downwind of various processes at Behr. A wind rose is shown on Figure 2. Winds were predominantly from the southeast, south, and northwest. The monitor site was directly downwind of Behr's hammer mill shredder (south and southeast of the trailer) about 25% of the time. Winds were directly from the Pb furnace less than 15% of the time – emissions from this process were captured in this study, however the monitor location does not represent the area of maximum impact.

Figure 2. Study period wind rose



Study Findings

Measured concentrations for 22 metals monitored as TSP are summarized below on Table 2. These metals had nondetect rates between zero and 85%, which is acceptable for data analysis. Thallium was excluded from analysis because its nondetect rate was 99%.

Table 2. Rockford, Illinois, metals data summary

Element, Symbol	Nondetect Rate, %	Full Study Average[a], ng/m^3	Health Comparison Value, ng/m^3
Antimony, Sb	20	225	
Arsenic, As	49	1.6	2.3[b]
Barium, Ba	36	3.4	
Bromine, Br	1	23	
Cadmium, Cd	0	4.2	5.6[b]
Calcium, Ca	0	3,529	
Chromium, Cr	12	13	42[bc]
Cobalt, Co	85	0.96	100[d]
Copper, Cu	0	46	
Iron, Fe	0	3,083	
Lead, Pb	0	57	(see NAAQS)
Manganese, Mn	0	69	300[d]
Mercury, Hg	43	0.33	300[d]
Molybdenum, Mo	0	27	
Nickel, Ni	1	13	42[b]
Potassium, K	0	280	
Rubidium, Rb	13	0.82	
Selenium, Se	25	0.41	20,000[d]
Strontium, Sr	0	6.9	
Thorium, Th	66	3.3	
Titanium, Ti	0	55	
Zinc, Zn	0	189	
a) Averages calculated using zeroes in place of nondetects.			
b) Concentration equivalent to 10-in-1-million excess cancer risk			
c) Assuming 2% of chromium is in most toxic hexavalent form			
d) Reference concentration (RfC) for noncancer health effects			

The Pb NAAQS is violated when any 3-month rolling average is higher than 150 ng/m^3 meter. EPA defines the potential to exceed the NAAQS as short-term monitoring or modeling with results greater than 50% of the NAAQS (75 ng/m^3). For air toxics, monitoring data are compared against health screening values for long-term (full study average) and short-term (1-hour, 8-hour, 24-hour, and 14-day peaks) health effects, as described on the below EPA website "Dose-Response Assessment for Assessing Health Risks Associated With Exposure to Hazardous Air Pollutants". Full-study averages and the long-term health comparison values are shown above in Table 2. The use of zeroes in place of nondetects causes calculated averages to be slightly underestimated: for example the full-study arsenic average is 1.62 using zeroes and 1.63 when one-half of the detection limit is used instead. There are a short-term health comparison values for only three toxic metals: 1) Arsenic has California EPA Reference Exposure Levels (RELs) for 1-hour peaks (200 ng/m^3) and 8-hour peaks (15 ng/m^3); 2) Cadmium has an ATSDR acute Minimum Risk Level (MRL) for 1-14 days (30 ng/m^3); and 3) Nickel has an intermediate MRL for 14-365 days (200 ng/m^3) http://www2.epa.gov/fera/dose-response-assessment-assessing-health-risks-associated-exposure-hazardous-air-pollutants

Lead results

Lead concentrations over the full study averaged 58 ng/m^3, with the highest 3-month average of 69 ng/m^3 (46% of the NAAQS) and the highest single month average of 82 ng/m^3 (54% of the NAAQS).

The specific hours with the highest lead concentrations are listed in Table 3. The greatest Pb spikes occurred exclusively on regular work days (Monday through Friday) and most often on Mondays. These peaks were all reported in the afternoon and evening hours, with the highest concentrations after 5 PM.

Table 3. Top twenty hours of highest Pb concentrations

Date	Day	Time	WD, degrees	WS, mph	Pb, ng/m^3
9-May-14	Fri	1:00 PM	226	8.5	1202
19-May-14	Mon	2:00 PM	134	12.7	1693
2-Jun-14	Mon	12:00 PM	216	8.2	1003
		2:00 PM	215	7.0	927
		4:00 PM	218	6.4	1501
		5:00 PM	212	5.8	2121
		6:00 PM	202	4.2	2411
12-Jun-14	Thurs	10:00 AM	245	4.1	1296
30-Jun-14	Mon	10:00 PM	165	3.4	1168
7-Jul-14	Mon	5:00 PM	215	2.8	2973
		6:00 PM	206	3.1	9798
		7:00 PM	184	2.4	2593
		8:00 PM	173	2.0	6602
27-Oct-14	Mon	2:00 PM	180	7.9	1629
4-Nov-14	Tues	3:00 PM	220	4.3	833
		4:00 PM	212	4.9	2839
		11:00 PM	214	4.4	1090
5-Nov-14	Wed	12:00 AM	216	4.6	5623
		2:00 PM	179	3.6	767
		10:00 PM	205	4.8	1205

The average Pb concentration for every hour of the week is shown on Figure 3, with 95% confidence intervals shaded pink. This graphic demonstrates that Pb levels in a typical week peaked Monday evening, levelled off Tuesday and Wednesday, then displayed secondary peaks on Thursday and Friday afternoons.

Figure 3. Average weekly pattern of Pb concentrations, ng/m^3

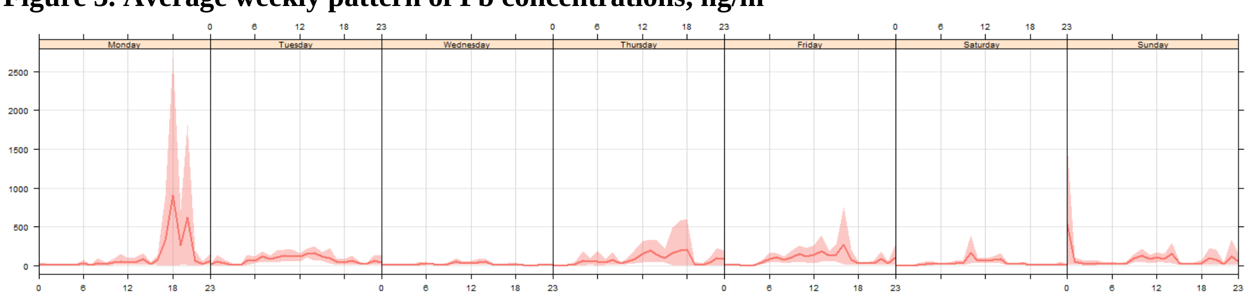
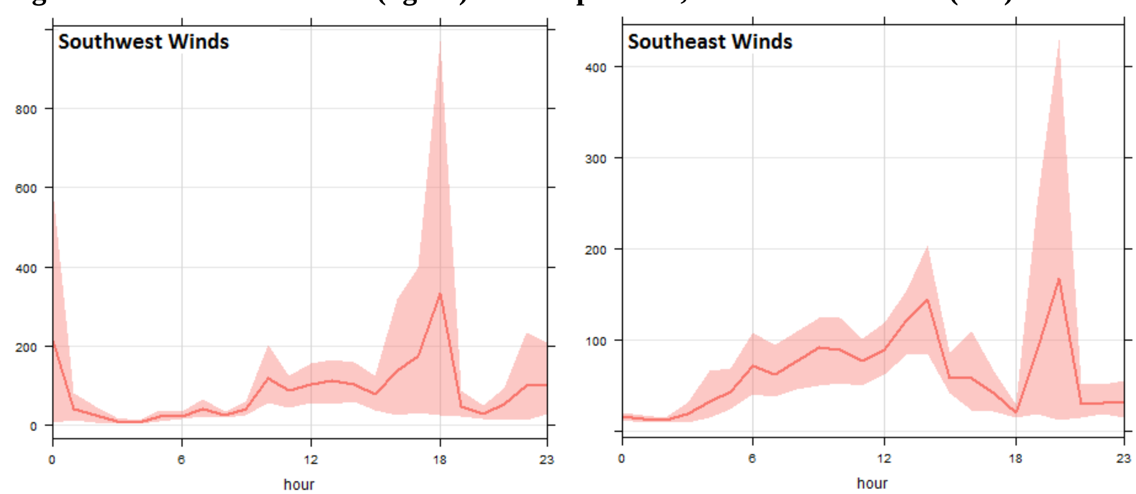


Figure 4 shows the percentiles of hourly Pb concentrations plotted by wind direction. The plot is overlaid on a site map and centered on the monitor location in order to show the orientation of the emissions source(s) relative to the monitoring trailer. This figure is a type of pollution rose, where the longest "petals" point toward the emissions point(s) of a given metal. In the case of Pb, the highest concentrations occur when winds are from the lead furnace; the shredder appears to be a secondary contributor of Pb.

Figure 4. Lead concentration percentiles plotted by wind direction, ng/m^3

To better distinguish emissions from the lead furnace as compared with the shredder, lead data were divided into two bins: wind direction from the southwest (190 to 360 degrees) and the southeast (0 to 190 degrees). Figure 5 shows the difference in the 24-hour pattern of ambient Pb when the wind is from either of these directions. Note that the y-axis in the two figures is different, as higher concentrations emanated from the southwest. These charts show that the lead spikes from the furnace are more extreme and correspond to a late-afternoon or second shift period. The shredder seems to have Pb emissions during regular work hours, plus a second "blip" after 7 PM that could be particle drift from the lead furnace.

Figure 5. Lead concentration (ng/m^3) diurnal patterns, winds from furnace (SW) vs. shredder (SE)



Arsenic results

Arsenic levels were higher than short-term screening values on several dates. No other toxic metals were measured at concentrations higher than the long-term health comparison values listed on Table 2. Arsenic exceeded California EPA's 1-hour REL on July 7th at 6 PM with a concentration of 291 ng/m^3. The 8-hour REL was also exceeded on this date and on four additional days, as listed on Table 4. Note that the 8-hour REL technical support document states "The 8-hour Reference Exposure Level is a concentration at or below which adverse noncancer health effects would not be anticipated for repeated 8-hour exposures which might include daily occupational, in-home or in-school exposures.. Due to the possibility of repeated exposure and the relatively slow clearance of arsenic compounds, the 8-hour REL is taken to be equivalent to the chronic REL." (see: p 111; http://www.oehha.ca.gov/air/hot_spots/2008/AppendixD1_final.pdf#page=75) The July 7th As spike coincided with extremely high Pb from the direction of the lead furnace. The other four periods of elevated As were characterized by slow winds (nearly calm, <1 mph) and variable wind direction, suggesting the source was close to the trailer. These events tended to occur in the late evening and overnight.

The As percentile plot in Figure 6 shows impacts from the lead furnace and shredder, as well as other operations at Behr on the east side of Seminary St. There may be As emissions from the area north of the shredder, i.e. the buildings and outdoor operations directly east and southeast of the trailer.

Arsenic day-of-week patterns are provided in Figure 7 (note different y-axes). Arsenic impacts from the lead furnace (Southwest winds) peak on Mondays, similar to the Pb trend. The source(s) southeast and east of the monitor also contribute additional As on Tuesdays, Saturdays, and Sundays.

Arsenic time-of-day (diurnal) patterns are shown on Figure 8; note different y-axes. The trends are very similar to what was seen for Pb in Figure 5: arsenic peaks at 6 PM when winds are from the southwest, whereas concentrations are distributed throughout the workday when there is a southeast/east wind.

Table 4. Periods of peak Arsenic concentrations

Date	Day	Time	WD, degrees	WS, mph	As, ng/m^3	As, 8-Hr, ng/m^3
3-Jul-14	Thurs	8:00 PM	356	0.5	12.0	15.3
		9:00 PM	349	0.4	58.2	
		10:00 PM	104	0.4	33.0	
		11:00 PM	1	0.6	5.7	
4-Jul-14	Fri	12:00 AM	125	0.6	3.1	
		1:00 AM	136	0.6	4.1	
		2:00 AM	69	0.2	3.5	
		3:00 AM	28	0.4	2.8	
7-Jul-14	Mon	4:00 PM	234	3.9	12.8	62.1
		5:00 PM	215	2.8	97.4	
		6:00 PM	206	3.1	291.3	
		7:00 PM	184	2.4	61.6	
		8:00 PM	173	2	23.7	
		9:00 PM	167	2	4.8	
		10:00 PM	152	3.5	1.7	
		11:00 PM	172	3.9	3.2	
13-Sep-14	Sat	9:00 PM	77	0.7	2.9	18.6
		10:00 PM	70	0.7	20.4	
		11:00 PM	61	0.7	28.1	
14-Sep-14	Sun	12:00 AM	48	0.5	48.1	
		1:00 AM	64	0.7	29.3	
		2:00 AM	82	0.8	11.7	
		3:00 AM	91	0.9	4.4	
		4:00 AM	95	0.9	3.7	
17-Sep-14	Wed	6:00 PM	356	0.6	13.4	16.4
		7:00 PM	333	0.6	25.7	
		8:00 PM	351	0.6	61.7	
		9:00 PM	332	0.6	0.0	
		10:00 PM	325	0.6	15.4	
		11:00 PM	318	0.3	8.9	
18-Sep-14	Thurs	12:00 AM	57	0.7	3.0	
		1:00 AM	14	0.7	2.8	
18-Oct-14	Sat	3:00 PM	0	2.9	6.2	14.7
		4:00 PM	21	0.8	0.0	
		5:00 PM	86	0.7	11.0	
		6:00 PM	60	0.3	2.4	
		7:00 PM	112	0.1	6.6	
		8:00 PM	91	0.5	10.2	
		9:00 PM	61	0.4	61.1	
		10:00 PM	114	0.8	19.9	

Figure 6. Arsenic concentration percentiles plotted by wind direction, ng/m^3

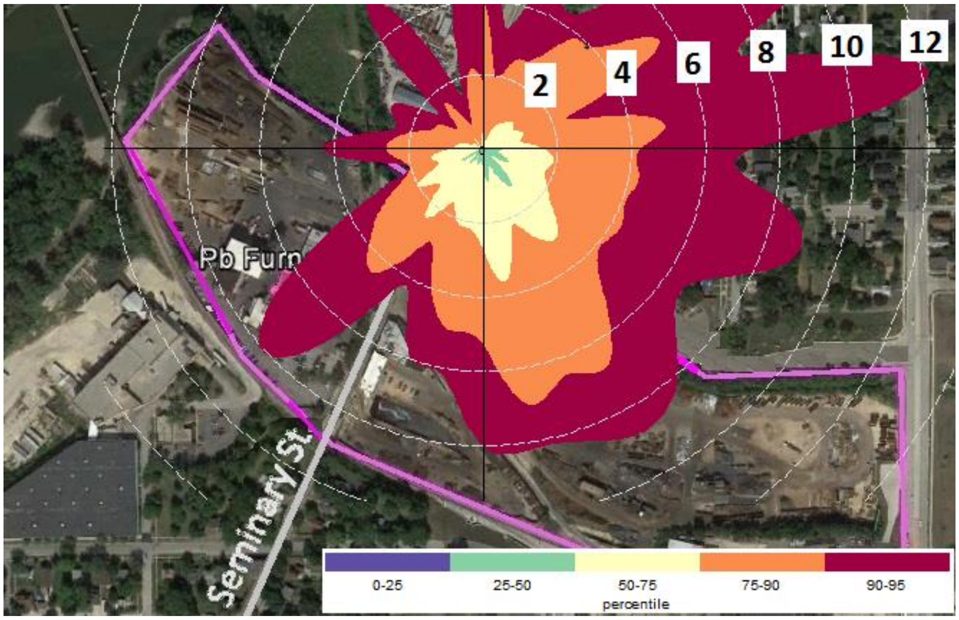


Figure 7. Arsenic day-of-week patterns (ng/m^3), winds from furnace (Southwest) versus shredder and other operations (Southeast)

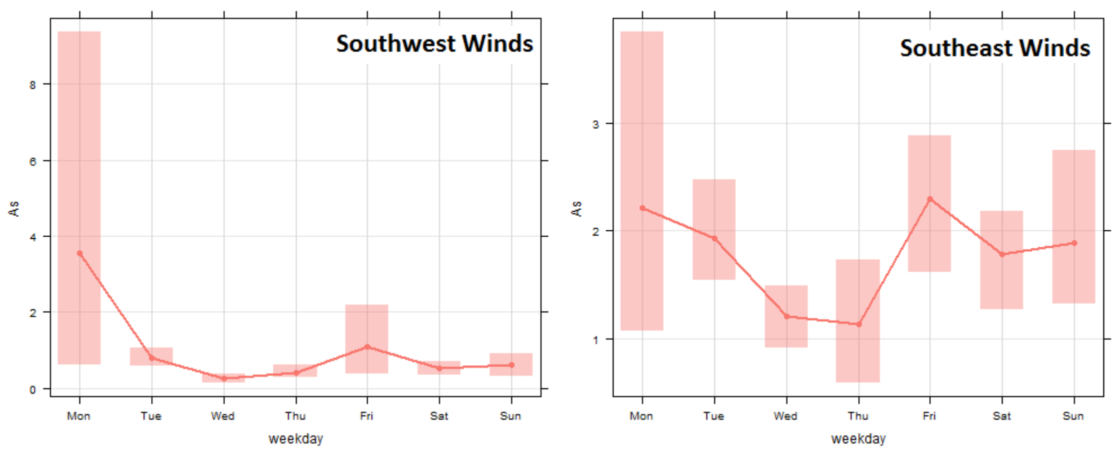
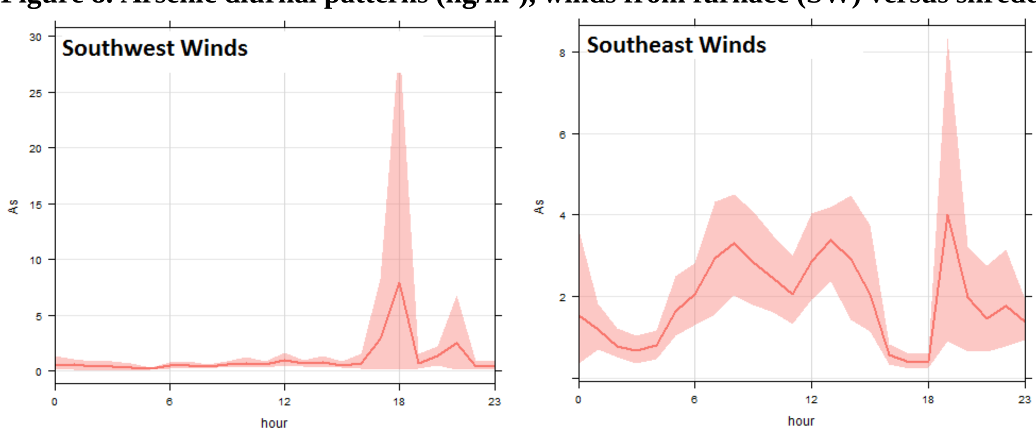


Figure 8. Arsenic diurnal patterns (ng/m^3), winds from furnace (SW) versus shredder (SE)

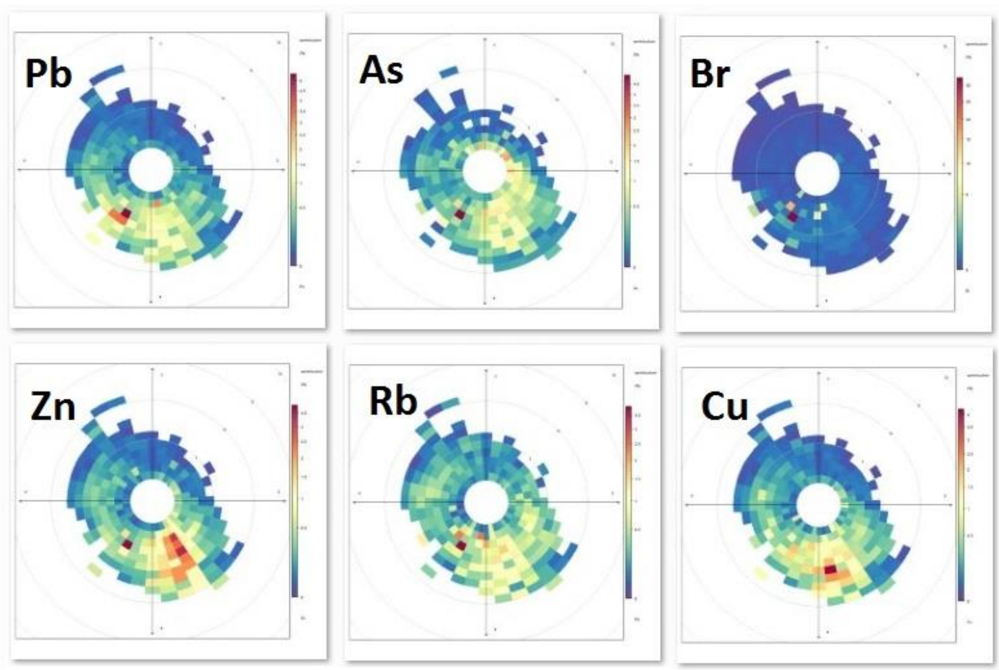


Relationship between Pb, As, and other metals

Lead and arsenic are moderately correlated with each other (R^2=0.33); these two metals have overlapping, but not identical sources. The peak concentrations driving risk for both appear to result from the furnace. There are similarities found in data trends of several other elements: both lead and arsenic are well correlated to bromine (R^2=0.52 and 0.51, respectively) and to zinc (R^2= 0.49 and 0.44 resp.). Rubidium is also correlated to lead, arsenic, and bromine (R^2=0.37, 0.29, and 0.49, resp.). Copper is also weakly correlated to Pb (R^2=0.22), but not to the other tracer metals.

The plots on Figure 9 show average concentration of metals when binned by wind direction and wind speed. Concentrations associated with a greater speeds are plotted further away from the monitor location (center), because stronger winds carry metals particles a further distance toward the monitor. These plots suggest that Br can be used as a tracer for Pb and As emissions from the furnace because the peak levels (dark red) emanate from the same area. Zn, Rb, and Cu show a mix of impacts from the furnace and shredder.

Figure 9. Key metals plotted by wind direction and speed, ng/m^3



Data trends for ferrous metals processing

Percentile plots for iron and several other steel components are shown on Figure 10. These metals are mainly emitted from Behr's shredder, which seems to process ferrous scrap, with lesser amounts emitted from the lead furnace. The data trends for iron shown on Figure 11 are typical of manganese, chromium, and other ferrous metals. The diurnal and day-of-week pattern is distinct from the lead trends observed in this study. Peak emissions occur during typical business hours (6 AM to 4 PM), in contrast to evening Pb peaks. Ferrous metals are highest on Tuesdays and Fridays, and somewhat elevated on Saturdays and Sundays. According to the Behr website (http://behrim.reachlocal.net/company-info/locations) ferrous scrap are dropped off from 8 AM to 4 PM on Monday-Friday and 8 AM to Noon on Saturdays. The steep drop in ambient As after 4 PM seen on Figure 8 and Fe on Figure 11 corresponds with this schedule.

Figure 10. Metals attributed to ferrous metal recycling, percentiles plotted by wind direction, ng/m^3

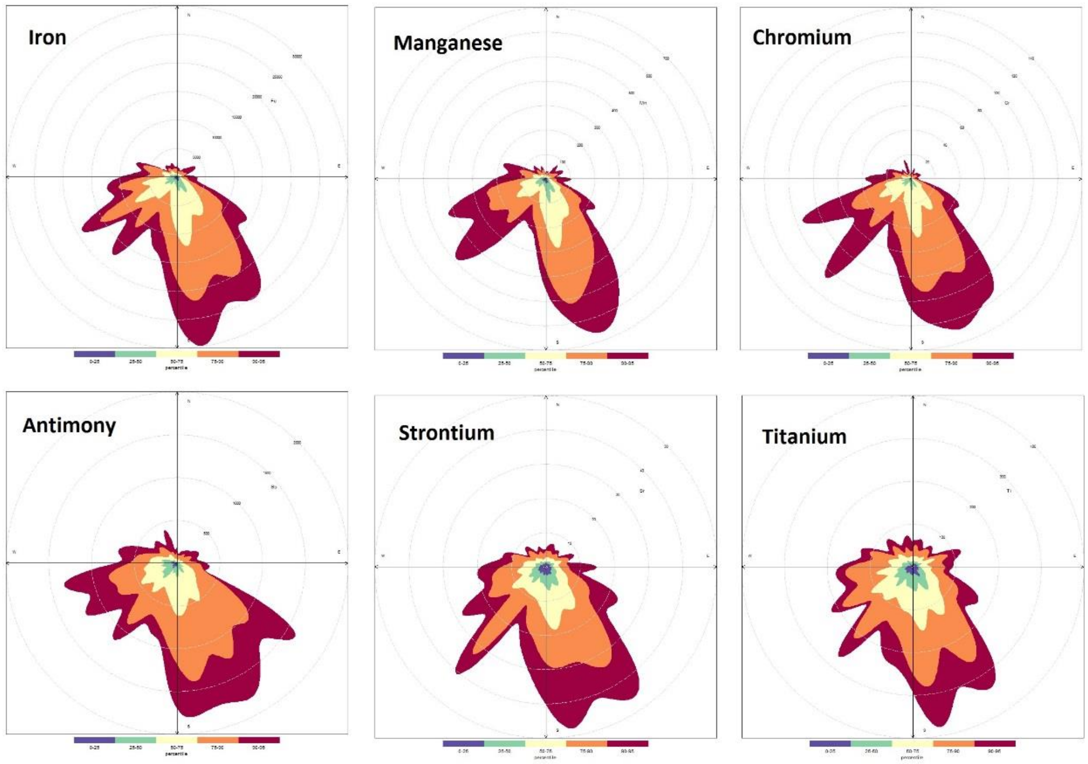
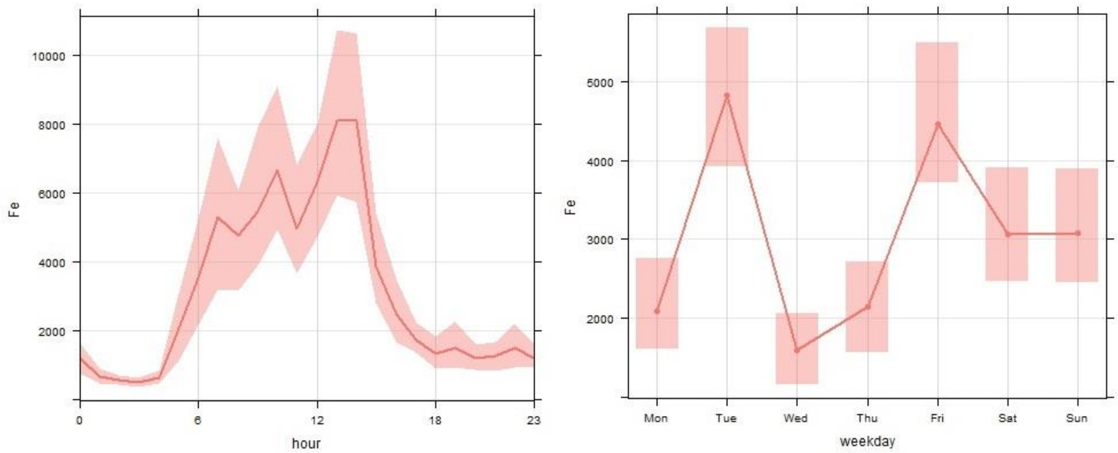


Figure 11. Iron diurnal and day-of-week trends, ng/m^3



Ambient arsenic is largely explained by the combination of emissions from the furnace and shredder. However there is evidence of As emissions east/southeast of the monitor site that are not consistent with with data patterns seen in metals that are tracers for the furnace (e.g. bromine) or the various ferrous metals processed at the shredder. There may be additional activities at the buildings north of Behr's shredder that are contributing As.

Summary and Conclusions

1. This short-term investigation showed that lead concentrations are approximately 50% of the NAAQS. This is sufficient evidence of the potential to violate the NAAQS in the long-term. EPA should require monitoring for a period of 3 years to assess attainment status.

2. Lead concentrations during the highest month averaged 80 ng/m^3 (53% of the NAAQS, which is 150 ng/m^3). The highest 3-month average was 67 ng/m^3 (44% of the NAAQS).

3. The EPA metals monitor was sited without the benefit of having site-specific meteorology or facility dispersion modeling to determine the area of maximum off-site impact from Behr operations. Lead concentrations in ambient air may be higher at other location(s) where EPA did not conduct monitoring.

4. Arsenic levels were higher than short-term health comparison levels on several dates. Arsenic exceeded California EPA's 1-hour REL (200 ng/m^3) on July 7th with a concentration of 291 ng/m^3. The 8-hour REL (15 ng/m^3) was also exceeded on this date and on four additional days. These arsenic findings also support the need for long-term metals air monitoring.

5. Ambient concentrations of other toxic metals were below EPA's long-term and short-term health comparison levels.

6. Data trends analyses show that dominant lead emission are from the area of the lead recovery rotary furnace on the west side of the Behr property. A lesser amount of lead appears to be emitted by the hammer mill shredder, likely as a contaminant of recycled ferrous scrap.

7. Peak arsenic levels correspond to lead spikes from the furnace, with the addition of As contributions from the shredder and areas directly adjacent to the monitor, north of the shredder.

8. The most extreme lead and arsenic emissions from the furnace occur on Mondays, late afternoon and evening, i.e. second shift, and on Fridays to a lesser extent.

9. When data are segregated by wind direction, secondary impacts from the shredder can be discerned and Pb/As trends track the data patterns of ferrous scrap metals, specifically iron, manganese, chromium, and several others. Ferrous scrap recycling emissions peak during daytime business hours (6 AM to 4 PM) on Tuesdays and Fridays, as well as the weekend.